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ABSTRACT

In 1971, the 25th Session of the Council for Mutual Economic Assistance (CMEA) adopted a Programme for the Development of Socialist Economic Integration. Later, part of this program became a program of cooperation in the field of oceanography, particularly the chemical, physical, and biological processes of certain important areas of the ocean. To pursue cooperation in this area, referred to as the "World Ocean Problem," five Socialist countries (Bulgaria, the German Democratic Republic, Poland, Romania, and the USSR) signed a special agreement in 1971. Cuba joined this agreement in 1977. The objectives of the cooperative efforts of these countries concerning oceanographic research are reviewed under the following headings: (1) the exploration of the hydrological structure of the ocean and the interaction processes between the ocean, the atmosphere, and the lithosphere; (2) investigation of biological productivity processes; (3) study of chemical processes in the ocean; (4) study of geological history and recent sedimentation processes in the ocean; and (5) application of submarine research technology to exploration of the sea. Descriptions are also provided of the efforts undertaken in upgrading the academic qualifications and professional standards of oceanographers in the member countries that signed the agreement. The major results of the joint research on the World Ocean Problem are delineated, and a list of principal publications of the cooperative countries is appended. (ML)

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Unesco reports
in marine science 38

Marine sciences in CMEA countries : programme and results of co-operation

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26	Global survey and analysis of post-graduate curricula in ocean engineering English only	1984
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30	Physical oceanography of the Eastern Mediterranean: an overview and research plan Report of a workshop held in Lerici, La Spezia (Italy), September 1983 English only	1984
31	MABAHISS/John Murray 50th anniversary: Marine science of the North West Indian Ocean and adjacent waters Report of a symposium on the occasion of the 50th anniversary of the MABAHISS/ John Murray Expedition (1933/34), University of Alexandria, Egypt, 3 to 7 September 1983 English only	1985
32	L'estuaire et la mangrove du Sine Saloum Résultats d'un Atelier régional Unesco-COMAR tenu à Dakar (Sénégal) du 28 février au 5 mars 1983 French only	1985
33	Coral taxonomy Results and recommendations of a regional Unesco (COMAR)/UNEP Workshop with advanced training Phuket Marine Biological Centre Thailand, 10-26 February 1984 English only	1985
34	Bibliography on costal lagoons and salt marshes along the Southern Mediterranean coast (Algeria, Egypt, Libya, Morocco, Tunisia) Available in Arabic, English and French	1985
35	Physical oceanography of the Eastern Mediterranean (POEM): A Research Programme. Reports of the Organizing Committee Meeting, Paris, August 1984, and the Scientific Workshop, Lucerne, October 1984 English only	1985
36	Méthodologie d'étude des lagunes côtières. Résultats d'un atelier régional réuni à Abidjan du 6 au 11 mai 1985 French only	1986
37	Principles of Geological Mapping of Marine Sediments (with special reference to the African continental margin) Available in English and Russian	1986

Unesco reports
in marine science 38

Marine sciences in CMEA countries: programme and results of co-operation

by:
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Countries on the World Ocean Problem

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PREFACE

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ABSTRACT

In 1971 the XXV Session of the Council for Mutual Economic Assistance (CMEA) adopted a Programme for the Development of Socialist Economic Integration. Later, part of this programme became a programme of co-operation in the field of oceanography. The Co-ordinating Centre created for this purpose developed a series of theoretical and field research projects aimed at enlisting all the Member Countries and creating a single international scientific team. During the 15 years of this programme's existence, a structure for joint research has developed. It consists of several Research Directions, such as exploration of the hydrological structure of the World Ocean and interaction processes between the ocean, the atmosphere and the lithosphere; investigation of biological productivity, chemical processes in the ocean; geological history and sedimentation processes and application of submarine research technology to exploration of the sea. Activities included a number of joint expeditions, meetings and publications.

Special academic training and upgrading of professional standards are among the tasks of the Co-ordinating Centre and publication of results of joint studies is underway.

The organizers feel that the experience of co-operation has shown that international experiments (expeditions, studies) is the best way of concentrating efforts and ensuring closer integration of co-operating socialist countries.

RESUME

A sa vingt-cinquième session, en 1971, le Conseil d'assistance économique mutuelle (CAEM) avait adopté un programme pour le développement de l'intégration économique socialiste. Par la suite, une partie de ce programme est devenue programme de coopération dans le domaine de l'océanographie. Le Centre de coordination créé à cet effet a mis au point une série de projets de recherche théorique et de recherche sur le terrain visant à favoriser la participation de tous les pays membres et à créer une seule et unique équipe scientifique internationale. Au cours des 15 années d'exécution de ce programme, une structure de recherche commune a été progressivement mise en place. Elle consiste en plusieurs directions de recherche - par exemple exploration de la structure hydrologique de l'océan mondial et processus d'interaction entre l'océan, l'atmosphère et la lithosphère ; étude de la productivité biologique et des processus chimiques dans l'océan ; histoire géologique et processus de sédimentation ; application des techniques de recherche sous-marine à l'exploration de la mer. Parmi les activités figuraient un certain nombre de campagnes de réunions et de publications communes.

Le Centre de coordination a notamment pour tâche d'assurer des cours spéciaux de formation théorique et l'amélioration du niveau professionnel. La publication des résultats des études communes est en cours.

Pour les organisateurs, cette coopération a montré que les expériences internationales (campagnes, études) constituent le meilleur moyen de concentrer les efforts et d'assurer une intégration plus étroite des pays socialistes qui y participent.

RESUMEN

En 1971, la XXV Reunión del Consejo de Asistencia Económica Mutua (CAEM) aprobó un Programa de Fomento de la Integración Económica Socialista. Ulteriormente, parte de este programa se transformó en un programa de cooperación en materia de oceanografía. El Centro de Coordinación creado a tal efecto elaboró diversos proyectos de investigaciones teóricas y sobre el terreno con miras a obtener la participación de todos los países miembros y a constituir un equipo científico internacional único. En el curso de los 15 años de existencia de este programa, se ha desarrollado una estructura de investigación conjunta que comprende diversas Direcciones de Investigación, como la exploración de la estructura hidrológica del Océano Mundial y de los procesos de interacción entre el océano, la atmósfera y la litosfera; la investigación de la productividad biológica y de los procesos químicos que tienen lugar en el océano; la historia geológica y los procesos de sedimentación y la aplicación de la tecnología de las investigaciones submarinas a la exploración del mar. Entre las actividades efectuadas cabe mencionar diversas expediciones conjuntas, reuniones y publicaciones.

Las tareas del Centro de Coordinación incluyen la formación universitaria especial y la elevación de los niveles profesionales, y se encuentra en curso la publicación de los resultados de los estudios conjuntos.

Los organizadores consideran que la experiencia de actividades en cooperación ha demostrado que los experimentos internacionales (expediciones, estudios) constituyen la mejor forma de concentrar los esfuerzos y de lograr una integración más estrecha entre los países socialistas cooperadores.

АННОТАЦИЯ

В 1971 году XXV сессия Совета Экономической Взаимопомощи (СЭВ) приняла Комплексную программу дальнейшего углубления социалистической интеграции, одним из разделов которой стала программа сотрудничества в области океанологии. Созданный для осуществления этой работы Координационный центр направил свою деятельность на подготовку серии теоретических и исследовательских работ в море с целью привлечения всех стран-участниц и объединения их в единый международный научный коллектив. В течение пятнадцати лет совместных работ сложилась определенная система организации исследований, состоящая из ряда направлений, таких, как Исследования гидрологической структуры морей и процессов взаимодействия океана, атмосферы и литосферы, изучение процессов биологической продуктивности, исследование химических процессов в океане, геологической истории и процессов современного осадкообразования, применение методов подводных исследований к изучению морей. Осуществляется работа по подготовке океанологических кадров для стран СЭВ, повышению их научной квалификации. Ведется деятельность по изданию трудов совместных работ. Опыт сотрудничества показал, что международные эксперименты наилучшим образом обеспечивают концентрацию сил и материальных средств заинтересованных стран, ведут к более глубокой социалистической интеграции.

مستخلص

فى عام ١٩٧١ ، أقرّت الدورة الخامسة والعشرين لمجلس المعونة الاقتصادية المتبادلة (كوميكون) برنامجا لتنمية التكامل الاقتصادى الاشتراكى . وأصبح جزء من هذا البرنامج ، فى وقت لاحق ، برنامجا للتعاون فى مجال الاقيانوغرافيا . وابتكر مركز التنسيق الذى أنشىء لهذا الغرض مجموعة من مشروعات البحوث النظرية والميدانية تستهدف مشاركة جميع البلدان الأعضاء وانشاء فريق علمى دولى واحد . وأثناء السنوات الخمس عشرة لوجود هذا البرنامج تبلورت بنية لاجراء بحوث مشتركة ، وتتمثل هذه فى توجيهات عديدة خاصة بالبحوث مثل استغلال البنية الهيدرولوجية للمحيط العالمى وعمليات التفاعل بين المحيط والجو والقشرة الأرضية ، واستقصاء الانتاجية البيولوجية ، والعمليات الكيمائية فى المحيط ، والتاريخ الجيولوجى وعمليات الترسيب وتطبيق تكنولوجيات بحث الأعماق البحرية فى مجال استكشاف البحار. وتضمّنت الأنشطة عددا من الرحلات الاستكشافية المشتركة والاجتماعات والمطبوعات .

ويعد التدريب الأكاديمى الخاص ورفع المستويات المهنية من بين مهام مركز التنسيق ، ويجرى نشر نتائج الدراسات المشتركة .

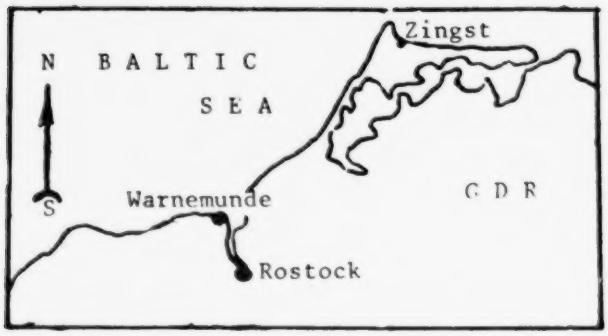
ويرى المنظمون أن الخبرة المكتسبة من التعاون تبيّن أن التجارب الدولية (الرحلات الاستكشافية ، والدراسات) هى أفضل وسيلة لتركيز الجهود وضمان التكامل الأوثق للبلدان الاشتراكية المتعاونة .

摘　　要

1971年，经济互助委员会（CMEA）第二十五届会议，曾通过一项《社会主义经济一体化发展计划》。此后，这项计划的部分内容，成为一项海洋学方面的合作计划。为此目的建立的协调中心，制订了一系列理论和实地研究项目，其目的是争取所有会员国加入和建立一个单一的国际科学组。在这项计划设立的十五年间，已建立起联合研究的结构。其中包括几项研究范围，如探索世界海洋之水文结构和海洋、大气和岩石层之间的相互影响过程；海洋生物学生产力和化学过程调查；地质史和沉积过程以及海底研究技术在海洋探测上的应用。活动包括一些联合考察、会议以及出版物。

学术性的专门培训和专业水准的提高均属协调中心的任务；联合研究的成果的出版工作正在进行。

组织者认为，合作经验表明，国际性试验（考察、研究）是集中力量和确保协作的社会主义国家进一步一体化的最佳方式。



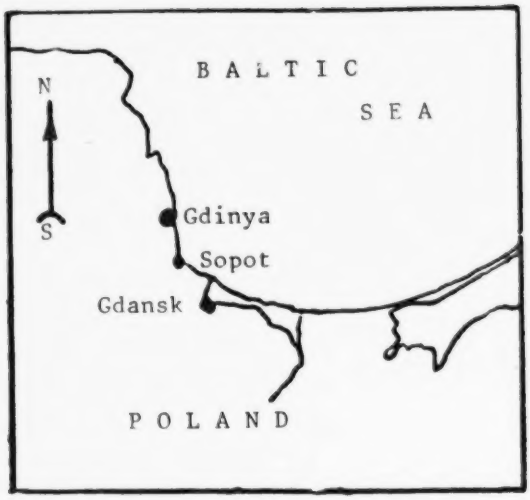


Fig 1. Geographical locations which are most frequently referred to in the text.

TABLE OF CONTENTS

Introduction 1

Research Direction 1.
Exploration of the hydrological structure of the ocean and the interaction process between the ocean, the atmosphere and the lithosphere 4

Research Direction 2.
Investigation of biological productivity processes 16

Research Direction 3.
Study of chemical processes in the ocean 25

Research Direction 4.
Study of geological history and recent sedimentation processes in the ocean 29

Research Direction 5.
Application of submarine research technology to exploration of the sea 34

Specialised academic training and upgrading of professional standards 38

Publishing activities 40

Conclusions 41

Annex
List of principal publications on the World Ocean Problem of cooperative countries (excluding bulletins) 43

INTRODUCTION

In 1971 the XXV Session of the Council for Mutual Economic Assistance (CMEA) adopted a complex Programme for Developing the Socialist Economic Integration. This programme, which was based on the experience gained during the preceding 20 years (1950-1970) of co-operation among socialist countries, identified the fundamental objectives and delineated directions of joint work for the next 15 to 20 years.

Co-operation in the domain of science and engineering was given a prominent part in the programme. In this sphere, the 18 most urgent and important problems were specifically determined. Three of these problems concerned the ocean: (i) the development of measures for the conservation of nature, (ii) the investigation of the ocean with the aim of exploiting its mineral resources and (iii) the study of chemical, physical, biological and other processes of certain important areas of the Ocean. To pursue co-operation within the latter subject (for the sake of brevity hereafter called the "World Ocean Problem") five socialist countries signed in 1971 a special Agreement.

The member countries: The People's Republic of Bulgaria, the German Democratic Republic, the People's Republic of Poland, the Socialist Republic of Romania and the Union of Soviet Socialist Republics developed a common research programme aimed at giving a boost to marine science in each country and obtaining some practical applications of results in sea-oriented industries. In 1977 this agreement was also joined by the Republic of Cuba. The initial plan of collaboration was rather imperfect since at that time the potential of individual countries and main tasks determined by the interests of national economies were not yet clear.

To develop joint research the countries/participants in the Agreement had to fulfill certain preconditions, the principal one being a rational correlation of common and national interests. Of considerable importance was a realistic assessment of scientific potential and possible forms of participation of scientific institutions.

To effect the organisation of systematic joint research on the World Ocean Problem, a Co-ordinating Centre with a staff of several persons was established at the Shirshov Institute of Oceanology, the USSR Academy of Sciences, Moscow.

In the first years of its existence, the Co-ordinating Centre directed much of its efforts to compiling a scientific forecast on the World Ocean Problem, which was based on the answers given by a large number of specialists to questionnaires. The object of this work was to single out the most important (high priority) themes and divisions of concrete research. The forecast was compiled in a relatively short time, with 150 scientists from five countries taking part in completing several questionnaires. The results of this work enabled the research programmes to be improved and to be brought more into line with current requirements.

In subsequent years, the system of formulation and utilisation of research programmes was definitely established. The Council of Representatives of the participating countries holds annual meetings during which members discuss a report of the Co-ordinating Centre and make final corrections in the working plans for the year to come before adopting them officially.

Delegates to the Council of Representatives are, with a very few exceptions, directors of leading oceanographic institutions. Thus the German Democratic Republic is represented by the Director of the Institut fur Meereskunde (Institute of Marine Research), Akademie der Wissenschaften der DDR; Republic of Cuba by the Director of the Institute of Oceanology, Cuban Academy of Sciences; the Socialist Republic of Romania by the Director of the Institute of Marine Research; the Soviet Union by the Director of the Institute of Oceanology, the USSR Academy of Sciences; the People's Republic of Poland by the Director of the Institute of Oceanology, Polish Academy of Sciences; the People's Republic of Bulgaria by the Chairman of the National Oceanographic Committee.

Another line of activity of the Co-ordinating Centre consists in the organisation of a series of *in situ* marine research projects that would attract scientists from all the participating countries and unite them into a single international scientific team.

The initial large-scale international experiments, with up to a hundred scientists from the countries then participating in the Agreement, were conducted on the Baltic coast at the Marine Observatory of Leipzig University in Zingst. During this first experience in real collaboration, scientists from the German Democratic Republic, the Soviet Union, Poland and Bulgaria, not only acquainted themselves with measuring devices and methods used by colleagues from other countries, but also conducted parallel measurements, compared their methods and discussed principal points of mutual interest. They worked as a unified scientific body striving towards a common goal. Thus, the atmosphere of teamwork was created.

An important stage in international co-cperation was marked by joint work on the Bulgarian shelf of the Black Sea on the utilisation of new underwater exploration techniques in oceanography. A Soviet undersea habitat "Chernomor" was transported to the vicinity of Cape Maslen; it was supported by a research vessel "Akademik L. Orbeli" of the Shirshov Institute of Oceanology.

In the course of 15 years of joint research, a definite system of research organisation has evolved. All subjects under study are grouped into five main divisions, or research directions:

RESEARCH DIRECTION 1.

Exploration of the hydrological structure of the ocean and the interaction process between the ocean, the atmosphere and the lithosphere.

RESEARCH DIRECTION 2.

Investigation of biological productivity processes.

RESEARCH DIRECTION 3.

Study of chemical processes in the ocean.

RESEARCH DIRECTION 4.

Study of geological history and recent sedimentation processes in the ocean.

RESEARCH DIRECTION 5.

Application of submarine research technology to exploration of the sea.

RESEARCH DIRECTION 1.

Exploration of the hydrological structure of the ocean and interaction processes between the ocean, the atmosphere and the lithosphere.

According to the joint research programme endorsed by the first meeting of the Council of Representatives in December 1971, the investigations in the 1971-75 period were to be centered on the study of the air/sea interaction with a view to improving the methodology of computing energy exchange and making hydrometeorological forecasts. This programme included the study of the interaction between the turbulent boundary layer of the atmosphere and sea waves, as well as the development and improvement of numerical models describing the interaction processes. It had been planned that this problem would be solved by means of joint marine experiments as well as by theoretical research. The International Symposium on the Mathematical Modelling of Air/Sea Interaction (September 1972, Varna, Bulgaria) became the first step towards the realisation of plans within Research Direction 1. The Symposium was attended by participants from Bulgaria, the German Democratic Republic, Poland, Romania and the Soviet Union, and by an observer from Yugoslavia. More than 30 papers presented at the Symposium dealt with problems of numerical modelling of large-scale circulation in the ocean and atmosphere, mesoscale phenomena, wind-induced waves and small-scale interaction and radiation proceses. The most complex and at the same time highly promising research in the field of numerical modelling of air/sea interaction became the central theme of the Symposium. Of special interest were contributions concerned with numerical modelling of seasonal patterns of oceanic circulation. As a result of the Symposium, the framework was established for the further development of research on the problems of mathematical modelling of air/sea interaction processes and of developing mathematical models of water circulation in the Black Sea, as well as perfecting and correlating with observation data the existing circulation models for the Baltic Sea.

In June 1972, exactly a year after the signing of the Agreement, the first joint expedition was conducted in the Baltic, on board the German Democratic Republic vessel "Professor Albrecht Penk" with scientists from the German Democratic Republic, Poland and the Soviet Union. In situ experiments in the field of turbulent diffusion of contaminants furnished new information on the transport of contaminants through the thermocline boundary. In 1973 and 1975 this research was continued, while the programme was expanded to include investigations of the spatial and temporal variability of hydrophysic fields and of the relation between small-scale turbulence and the background conditions largely responsible for it. The results obtained were described, in particular, in a joint (the German Democratic Republic, Poland and the USSR) monograph "Investigations of water dynamics of the Baltic" and in the Co-ordinating Centre Information Bulletin No.5.

The first international sympoisum and first joint expedition had a scientific impact on the co-operating countries. In summarizing the results of international co-operation during the whole of the period, the significant influence of these two events on the content and shape of subsequent co-operation of member countries can be noted. Firstly, they brought about the establishment of professional contacts between specialists from Bulgaria, The German Democratic Republic, Poland, Romania and the Soviet Union, which made clear the existing scientific interests and divergences in research techniques. Secondly, the cooperation programmes which were compiled annually within the framework of the World Ocean Problem became integral parts of national programmes and thus contributed to the emergence of new research institutions (such as the Institute of Marine Research (re-named in 1984 the Institute of Marine Research and Oceanology), Bulgarian Academy of Sciences). Thirdly, regular contacts and consultations of scientists and co-ordination of plans have finally resulted in the stabilization of the major divisions of Research Direction 1.

Thus as early as October 1973, the 4th meeting of the Council of Representatives included divisions "The study of the fine structure of the upper oceanic layer", and "Mathematical modelling of main physical fields in the Baltic and Black seas". The meeting also decided to broaden the sphere of joint theoretical, experimental and expeditionary research in the forthcoming five-year period (1976-1980). In 1985, at the 6th meeting of the Council of Representatives, the scope of this theme was widened to incorporate divisions concerned with studying the turbulent diffusion of contaminants and lithodynamic processes in the near-coastal area of the sea. Thus, three years after co-operation was started, the research had already acquired a regular character and had begun to develop at a steady rate.

The following table shows the growth in the number of institutions of member countries that took direct part in joint research in the period from 1972 to 1980.

Number of participating institutions in Research Direction 1.

Country	1972 Total	1972 Acad of Science System	1974 Total	1974 Acad of Science System	1980 Total	1980 Acad of Science System
Bulgaria	3	1	6	3	4	3
GDR	1	1	3	1	3	1
Cuba	-	-	-	-	1	1
Poland	1	1	2	1	3	2
Romania	1	-	1	-	1	-
USSR	1	1	1	1	5	4
Total	7	4	13	6	17	11

During the period of co-operation, the total number of institutions grew by a factor of 2.5, and the number of academic institutions by a factor of 3. The role of the institutes from the academies of science was especailly high in Bulgaria and the Soviet Union. In each country there emerged leading institutions which made the largest contribution to co-operation within the Research Direction 1. These institutes included the Institute of Oceanology, Bulgarian Academy of Sciences; Institute of Marine Studies, Academy of Sciences of the German Democrataic Republic; Institute of Oceanology, Academy of Sciences of Cuba; Institute of Oceanology, Polish Academy of Sciences; Institute of Water Engineering, Polish Academy of Sciences; Romanian Institute of Marine Research; Shirshov Institute of Oceanology, USSR Academy of Sciences. These organisations have a large staff of highly qualified research personnel and have all necessary scientific equipment and research vessels.

It has been demonstrated in practice that international experiments are the best way to secure the concentration of human potential and material resources of the countries concerned. Dozens of research workers from Bulgaria, the German Democratic Republic, Cuba, Poland, Romania and the Soviet Union, armed with the newest instrumentation systems are involved in team work in common programmes envisaging a wide range of observations. To facilitate the implementation of programmes, this international group of research workers was divided into special task groups. The functions of management and control over the course of these experiments belong to the scientific council consisting of leading specialists, whereas general co-ordination is performed by some prominent scientist of a host country. All preparatory work is done by the Co-ordinating Centre. During the experiment a scientific seminar is regularly convened, at which participants present papers reflecting the up-to-date state of knowledge on the theme of the experiment.

On termination of the field cycle, the processing and analysing of the data obtained is performed initially by national teams and at a later, closing stage by international groups organized by the Co-ordinating Centre in one of the participating countries. The final stage consists of holding a closing seminar or Symposium (usually 1.5 to 2 years after the in situ experiment), and publication of relevant papers based on research material.

Other important forms of co-operation are co-ordinated theoretical research, international symposia and seminars, sessions of expert groups and working meetings devoted to developing working plans, as well as the publication of joint monographs and collections of papers. In cases when a professional trip abroad is required, the collaborating institutes exchange a similar number of visiting scientists on a bi-lateral basis.

In the course of the year, the programme of international experiments became more diversified and specific. Thus during the first international experiment EKAM-73, the research was focused on the following subjects: vertical and horizontal flows of heat and moisture, as well as impulse flows at various levels in the near-surface atmospheric layer under conditions of horizontal inhomogeneity between the atmosphere and the underlying surface; the structure of the thin laminar sublayer of air and of vertical flows transversing it; the influence of the near-coastal varying water depth and of the distance from the shoreline on hydrodynamic fields of wind, surface waves and sea currents.

The research programmes using the "Lubiatowo" (Poland) and "Kamchia" (Bulgaria), (fig.1) experimental ranges were much wider in scope and envisaged hydrodynamic and lithodynamic research. Measurements of currents, average tempereature field, internal waves, fine structure of the hydrophysic fields and turbulence were carried out. The processes under study included also the diffusion of contaminants and air/sea interaction.

The research work on "Lubiatowo" and "Kamchia" experimental ranges involved the use of research vessels. Buoy stations with current meters were set and hydrological surveys were performed. Because the observations were so comprehensive, it was possible to study the generation mechanisms of water movement at various scales and the interaction processes between those water movements. Assessment of some elements of the heat and energy budget of the sea was also made. The object of the experimental measurements consisted also in attaining a better understanding of the waves transformation in the near-coastal area, of their spectral structure, as well as establishing directional spectra, studying the field of orbital and transfer velocities and measuring concentrations of suspended sediments.

The study of turbulence and turbulent diffusion of contaminants at sea was carried out both during the joint experiments and at a national level. At the International Symposium in Warnemunde, German Democratic Republic (December 1978), 20 papers by specialists from Bulgaria, the German Democratic Republic and the Soviet Union summarizing results of research of the previous years were heard and discussed.

It became possible in the Soviet Union, from expeditionary and theoretical research on the fine structure of hydrophysic fields and propagation of passive contaminants in a stably stratified medium, to define some peculiar features in the vertical structure of the small-scale turbulence field in the ocean. The applied aspects of the study of marine turbulence and turbulent diffusion, as well as methodological research in connection with the experimental study of diffusion processes, opened new lines of conceptual development. New data on the spectral characteristics of concentrations of passive contaminants and on the turbulent interchange between the surface and deep layers of the sea have been obtained. The experimental research on the processes of vertical exchange of passive contaminants through the thermocline has been initiated. The characteristics of turbulent exchange in the Baltic have been quantitatively estimated.

In 1980, the Co-ordinating Centre organized the <u>in situ</u> testing of a hydrophysical instrument probe intended for exploring the fine structure of the temperature, salinity and density field in the ocean on board the hydrographic vessel "Zodiac" (USSR). The probe had been jointly created in 1979-80 by Polish and Soviet workers. The tests in natural conditions have revealed complete readiness of the probe for on board operation at sea. During this cruise, measurements were also made of the fine structure of temperature and electric conductivity in the Baltic Sea.

In the German Democratic Republic, scientists have studied the dependence of the geometrical shape of a passive contaminant patch on the background hydrological conditions and, with the use of aerial photographic survey, the characteristics of diffusion processes in the

surface layer of the sea. Laboratory and in situ investigations of small-scale turbulence and temperature field fluctuations have been performed. A multi-channel water-sampling device for use at various depths has been designed and a prototype for hydrological and hydrochemical research was made.

In Bulgaria, the experimental study of meso-scale turbulence in near-coastal areas of the Black Sea has been carried out.

Considerable progress has been made in the sphere of research connected with the modelling of the main hydrophysic fields of the Baltic and Black Seas and certain areas of the Atlantic Ocean (equatorial area and upwelling zone off northwest Africa).

The problem of the modelling of currents and other physical characteristics of the Baltic Sea is also being tackled. At a Working meeting in Moscow in 1978, it was decided to start work on a new advance model of circulation in the Baltic. In this connection, a new approach to the general equations for the water circulation problem has been developed. It has been shown that, in modelling Baltic hydrophysic fields, it is necessary to take due account of external water exchange which amounts to approx 70 per cent of the annual water budget of the basin. To establish the variability and predict the exchange, it had been necessary to ascertain its dependence on the global and local atmospheric processes. Principal factors governing the exchange of water have been established, and the impact of local wind-induced transfers on the variability of water exchange through the Danish straits has been evaluated. The mathematical analysis of the interrelation of the water exchange and prevailing wind flows over the straits with the atmospheric macroprocesses has revealed that it can be employed in developing methods for long-term prediction of these elements and, consequently, in compiling forecasting models of hydrophysic fields. Incidentally, the general principles for modelling of the Baltic Sea as an integral geographical body have been developed.

The research in the domain of mathematical modelling of the hydrophysic fields in the Black Sea included the formulation of a non-linear model of the water circulation which takes account of the specific physical-geographical conditions. Calculations were performed according to a diagnostic model (three dimensional density field) and a prognostic one (density field calculated from diffusion densities equation). The results of the calculation were used to evaluate the contributions of individual factors to the formation of the Black Sea currents. Analysis of the available observation data shows that the mainstream flow in the Black Sea is subject to wave-like lateral motion (meandering) in relation to its mean path. The developing meanders may well become transformed into separate eddies resembling Gulf Stream rings. This phenomenon served as a foundation for constructing a theoretical model for investigating the possibilities of meander formation in the Black Sea.

Studies which have been fulfilled in the framework of the World Ocean Problem include research of the open part of the ocean. Thus in the modelling of currents of the African upwelling area, a new approach of a quasi-geostrophical model and an essentially non-linear model have been proposed. Both these models use equations to describe the ocean level. Concrete calculations were performed for a near-shore area off northwestern Africa from given density, wind and bottom

topography fields. Since the re-calculations are based on observation data, they are of practical interest. It has been demonstrated that, in the upwelling area, there exists a definite interdependance between water circulation pattern, shoreline geometry and bottom topography.

The major part of sediment transport obervations within the framework of the World Ocean Problem is performed under natural conditions. The lack of reliable techniques and some principal difficulties (such as that of distinguishing between suspended matter and entrained sediments) continue to hinder organisation of observations on bottom particle movement at sea. Therefore, research was focused mainly on studying the dynamics of suspended material which included the following:

(i) collection of reliable data on the detailed characteristics of the distribution of concentration and content of suspended sediments in the highly saturated near-bottom waters of the coastal zone (1.5 to 2m from the bottom) under stormy conditions;

(ii) testing and further development of the existing hypotheses on the dynamics of suspended sediments on the basis of information obtained;

(iii) development of new hypotheses required for producing a model of the storm distribution of suspended material in the upper shelf zone. Joint research was based on theoretical studies and laboratory experiments performed earlier, as well as on data and

experience obtained through in situ research effected at a national level.

The "Kamchia" experimental base in Bulgaria, effective since 1977, provided facilities for continuous measurements in stormy conditions.

The research programmes of "Kamchia - 1978 and 1979" undertook to solve the following problem: to determine the absolute concentrations of suspended sediments over extensive areas of the sea. The solution to this problem taken together with the hydrodynamical observation of the water masses transport permits the determination of the most critical characteristic of a sediment flow, which is its discharge.

In 1979 the marine scaffold gallery of "Kamchia" was considerably damaged during an outstandingly severe storm. It was decided to build a new capital pier gallery and, on shore, a complex of laboratory facilities. Thus a new and technologically advanced experimental base on the Black Sea coast, belonging to the Bulgarian Academy of Sciences, came into existence; it was given a new name "Shkorpilovtsy". Investigations under Research Direction 1 were commenced at the "Shkorpilovtsy" base in 1983 and are now progressing at a good pace and becoming more diversified.

The results obtained at the "Kamchia" base were summed up in three volumes of collected papers under the title of "Interaction of the atmosphere, hydroshpere and lithosphere in a sea coastal zone. Results of international experiments Kamchia-77, Kamchia-78 and Kamchia-79" (Published by the Bulgarian Academy of Sciences in 1980, 1982, 1983).

Specialists from 20 scientific institutions of Bulgaria, the German Democratic Republic, Romania and the Soviet Union have been working together in international reserarch groups, many of which came to be stable creative teams; they have developed a common theoretical basis and strategy of research. These investigations deserve serious consideration, with respect to the methodological level, the scope of observations and the newness and significance of results obtained. They were an extension and development of earlier research in Zingst (1973) and Lubiatowo (1974 and 1976) and dealt with major problems of the coastal zone dynamics, such as the wind field over the sea, air/sea heat and mass exchange, wind-induced waves, wave velocities in shallow water, dynamics of suspended sediment in the coastal zone, water circulation, turbulent diffusion and internal waves.

Aside from purely academic results, an important consequence of the research was the creation of a modern observational range including an instrumental gallery which is built accross the most dynamic part of the coastal zone, and separates deep water instrumental piles and buoys. All those observation posts are connected by cables with the shore laboratory, thus providing the necessary prerequisites for central control and management of conducted experiments.

The principal findings as described in the abovementioned books are discussed below.

Heat and mass exchange between the sea and atmosphere

Research in this field was conducted in 1979 and is reported in the volume "Interaction of the Atmosphere, Hydrosphere and Lithosphere in the Near-Coastal Zone of the Sea . Results of the Kamchia-79 International Experiment", published by the Bulgarian Academy of Sciences in 1983. The book contains the decription of the gallery and analysis of the observational data on the vertical fluxes of momentum, heat and moisture. These results were used to identify the form of the similarity functions of the Monin-Obukhov theory and the influence of stratification dependent on the characteristics of the air/sea interaction; this enabled the parameteration of the equation of heat and mass exchange between the sea and atmosphere.

The book presents the results of measuring the thermal characteristics of the surface water layer and analysing the thermal balance components in this layer. Data on the shoreward transport of spray was obtained through experiments and have been processed. The data from simultaneous measurements of wave spray and turbulent moisture exchange permit the evaluation of the intensity of mass exchange between the sea and atmosphere under stormy conditions.

Wind generated waves

Research on the wind-induced roughness of the sea surface has considerably expanded and refined the existing concepts on the statistical characteristics of waves in deep water and of the waves' transformation in the shallow coastal zone. A systematic experimental study was made of all the dynamic characteristics of wind-generated wave momentum, energy and action, and their relationship to the wind

speed and the degree of surface roughness. This enabled the evaluation of the relative role of momentum;, energy and fluxes in the wave dynamics and to determine the fundamental role of the wave action flux in the shaping of the wave spectrum . On the basis of these research results, a simple single-parameter theory for predicting wind-induced waves from the wind speed, wind duration, time and wind fetch has been evolved and experimentally tested. Some testing was also done on the methodology that is in current use in the Soviet Union for predicitng wind-induced waves in shallow waters. New empirical equations were derived for the integral functions of the wave height and period distributions. The dispersal of wind-induced waves, which exhibits marked differences from the linear theory at a small scale, has been experimentally studied.

Wind Field in the Coastal Zone of the Sea

Using a large amount of data, the variabilities of the sea surface friction coefficient and the roughness parameter have been assessed at various speeds and directions of the wind, during different stages of development of the wind - induced roughness of the sea surface, and at various distances from the shore. It was demonstrated that a low flat shore, with a relatively uniform sand and grass surface,has an impact on the dynamic properties of the near-surface atmospheric layer to a distance of up to one kilometre offshore. Counter to expectations, the transition from offshore to onshore wind brings about a decrease in the momentum, flow and friction coefficient with rising wind speed; the regime changes from "quite rough"for a wind from land to "smooth" for a wind crossing the shoreline , and to "super smooth" for a wind from offshore. In this case, the process of transformation of the hydrodynamic properties is slow, lagging behind the quicker changes in the wind direction. A knowledge of this consequence is essential for analysing observational data in the coastal zone.

The analysis of local wind speed profiles (with an averaging term of 60 seconds) has ascertained that the behaviour of the logarithmic part of the profile over the water surface in the absence of a measured value of the roughness parameter is characteristic of solid underlying surfaces. From this analysis, an understanding can be obtained of the factors causing a wide range of variation of this parameter during even short time spans. Because of a strong short-period variability of the integral air flow velocity, the wide range of variability of the roughness parameter seems to be closely coupled with velocity shear changes. Such an analysis seems new and is of value for improving our knowledge of the dynamics of the wind flow over the sea.

Some of the research dealt with the role of high-frequency gravity waves in forming sea surface roughness. The results of <u>in situ</u> measurements substantiated by laboratory experiments reveal that a prominent part is played by high-frequency wind-induced gravity waves in the air/sea interaction.

A theoretical analysis of the wind field interaction with waves in a shallow sea has shown that, in contrast to the case of the deep sea, when the roughness parameter decreases with growing waves, roughness of a shallow sea may well increase with diminishing frequency

of the spectral peak of waves; this is caused by the imbalance between the wind and the wave roughness as well as by the dynamic nature of the roughness parameter.

Kinematics of Shallow Waters

Research in this line was a continuation of an exploratory programme begun by the Shirshov Institute of Oceanology at a marine range off Crimea. The choice of objectives has been justified: at present, the water exchange due to rip currents occuring in the so-called "circulation cells" is comparatively well studied, whereas the compensation outflow of under-currents, which cause a complex vertical profile of mass transfer, remains understudied. The scheme of a two-layered storm circulation which had been put forward after measurements off Crimea, was born out by subsequent observations. New data show that this scheme holds true for smooth submarine slopes, as well as for severe storms with average wave heights of up to 1.2 metters.

Fluctuations of the transport velocity with a period of several minutes have been identified. An idea has been advanced that these fluctuations are connected to the mechanism of surf beating.

An important finding was the observed alteration of the frequency structure of the wave velocity field in the course of the field's distortion as the surf zone is approached; it can be attributed to the transfert of the energy of water transport in the high-frequency range. During localized wave breaking, the wave pattern of the water movement is on the whole maintained, but the energy of the higher harmonics passes into turbulence energy.

Another problem is the development of a method for the calculation of wave velocities in shallow areas; so far no reliable relationships between wave velocities and sea surface roughness parameters have been found. The Kamchia experiments amassed unique information on the horizontal components of orbital velocity in the surf zone, from which was derived an equation for the velocity curve under the crest of a breaking wave. Such essential parameters, as the statistical characteristics of the velocity distribution are also available.

Sediment transport in coastal zone

Research on sediment transport covered the area from the water's edge to a depth of 18-20 metres. The main emphases were placed on the study of the dynamics of suspended sediments and the short-term form changes of the bottom, as well as on the examination of the structural patterns of the upper sediments covering the beaches and the shelf.

The three year research period proved to be sufficient for practical achievements: the development of the instrumentation and the perfection of the techniques for measuring the absolute concentration of the suspended sediments in rough weather from the pier gallery. Attention is drawn to the thorough methodological approach used, and the simplicity, mobility and reliability of the instruments developed.

For storms of medium strength, a qualitative description has been given of the field of the suspended sediment concentrations, averaged throughout the storm period, and of the sediment composition for the whole width of the coastal zone. Prior to this research, simultaneous measurements across the nearshore coastal zone had not been made. The scope of the research included the pattern of variability during a storm of the suspended concentration field and the sediment composition with changes in wave parameters. It has been shown that a migration of the zone of intensive sediment suspension over the shelf is associated with shifts of the wave breaking zone along the profile. Also the observed suspended sediment concentration profiles were quantitatively described and calssified by type. Such detailed examination of storm processes also constituted a pioneering research.

From the summing up of data reported in publications and data obtained by in situ measurements, a semi-empirical model for calculating the absolute concentration profiles of suspended sediments and their mean particle size has been put forward. As yet the mode cannot be viewed as universal, but as an empirical generalization it seems to be better founded than others.

The study of the short-term changes of the bottom profile during a storm has established the relationship between the zones of sediment accumulation and erosion and the position of wave breaking. Empirical equations have been presented for estimating the values of the short term bottom form changes which seem to be reliable within a certain range. This information is useful for some applied problems.

It comes to light that appreciable amounts of suspended matter exist at a depth as great as 30 m in the Black Sea. A considerable amount of suspended material at such depths even during medium-strength storms indicates that the limit of suspension of clastic material lies seaward from these depths. It became possible to have some understanding of the formation and flow of suspended material and of the pattern of its distribution through a water column in stormy conditions in zones of differing dynamic activity.

Water circulation, meso-scale turbulence and turbulent diffusion

An analysis of the water circulation over the continental shelf has been based on automated buoy station data. This analysis has indicated that, under conditions of frequently changing atmospheric circulation, there occurs a restructuring of the water current field, which causes an instability of water, the existence of counter-flows both vertically and horizontally, and complicated patterns in the vertical profiles of current velocities.

Fluctuations of inertial character (with periods of 17 to 24 hours) and synoptic character (periods of 3 or 4 days) have been identified, and it was established that the length of the periods with relatively stable currents did not exceed 4 days.

From current measurements at automated buoy stations, it has been possible to identify the synoptic and inertial fluctuations of currents and the influences due to bottom topography. It has been shown that the spectral energy of the inertial fluctuations is of

maximum magnitude in the surface and deep layers. A significant feature is that the shifting character of currents is manifested in the anisotrophy of the turbulent energy and momentum exchange ellipses. The anisotrophy parameters are dependent on the value and stability of current velocities. The spatial variability of the turbulent exchange coefficients has been analysed. Its values in the area explored are higher than in other regions of the Black Sea. Exchange processes are seemingly more strongly developed in the Bulgarian shelf zone than over the steeply sloping shelves of Crimea and the Caucasis.

The pattern of variability of the maximum concentrations of inert pollutants with increasing distance from their original sources has been determined. The relationship between the horizontal diffusion coefficients and the scale of the phenomenon is discussed in the aforementioned book.

From the data on correlation functions and spectral density functions for dye concentration fluctuations, there were revealed multiple diffusion regimes and a wide size variety of turbulent eddies.

Internal waves

A complex research programme using special vessels and buoy stations has revealed the spatial and temporal variability of the temperature field in coastal waters and its statistical characteristics. Thus a generalized spectrum of the temperature fluctuations for coastal waters has been determined over a wide frequency range (from inertial to turbulent fluctuations).

The variability of the field of internal waves in the thermocline has been established for different hydrometeorological conditions. The patterns of the generation of internal waves as a function of wind speed have been determined. It was experimentally demonstrated that internal waves can break, giving rise to thermal inversion interlayers. A study has been made of the temporal evolution of the internal wave spectrum and of the vertical coherency of temperature fluctuations with depth in the thermocline. This study has revealed that the spectrum of temperature fluctuations for the autumn period, in the range from the inertial frequency to the mean Vajsala-Brent frequency, is close to the universal spectrum.

Turbulimeter measurements were used to plot the spectra of marine turbulence and to assess the horizontal and vertical coefficients of momentum exchange and energy dissipation.

The changes in the intensity of turbulent heat exchange in the marine coastal zone were determined from a special platform mounted in a water depth of 6 metres. Estimates of the Cox value have enabled to evaluate the role of individual dynamic factors in such exchange.

The research results collected in the described volumes have not only an academic but a practical value. For example, they may be used for engineering surveys preceding offshore construction projects, designing underwater communications; assessing the impact of wind, waves and sediment drift on various offshore structures, devellopping mariculture, carrying out nature conservation actions, reclaiming mineral resources and furthering recreational use of the sea.

The programme of co-operation for 1981-85 envisaged some changes against those for 1976-80. The preceding five-year period put much emphasis on the development of new methodologies and the improvement of the existing ones. The new five-year term was marked by using these methodologies for new scientific results concerning the study of air/sea interaction processes, turbulence and diffusion. In addition, it was planned to develop numerical models of hydrological fields in the Black Sea and the Baltic. The intended spheres of application of the models are hydrometeorological and fisheries forecasts. It was also planned to produce methodological recommendations of practical value for offshore construction and surveys in the coastal zone.

The series of experiments conducted at the Shkorpilovtsy Station in 1983-1985 have furnished new data in all the divisions of the programme. Substantial work has been done in connection with testing and completing the recording and measuring instrumentation.

The Shkorpilovtsy Station is used to stage controlled in situ experiments in the spheres of sea dynamics, air/sea interaction, turbulent diffusion and sediment transport of the shelf's upper zone.

Recently, investigations into the processes of interaction between hydrotechnical structures and the sea have been commenced. It is expected that new achievements will continue to be realized under the various subjects that together constitute Research Direction 1.

RESEARCH DIRECTION 2

The investigation of biclogical productivity processes of the Ocean.

The topic of marine biology was originally formulated as "The Study of Biological Processes of the Ocean". However, at the first session of the Council of Representatives in Moscow, in December 1971, four principal directions of common research were laid down and adopted for subsequent years, among which the second was "the study of biological resources of the ocean". This concerned the investigation of the climatic and hydrologic conditions and the assessment of the living resources of the Baltic, the Black Sea and certain areas of the Atlantic Ocean.

The original wording enhanced the possibility of a duplication of effort with the system of co-operation carried out by the fisheries organisations of the socialist countries and within the special agreements for the Baltic and Black Seas. That is why at the First Session of the Scientific and Technical Council in 1972, attention was drawn to the capital importance of co-ordination and mutual exchange of information on the proposed research programmes with the so-called Mixed Commission on Fisheries of CMEA countries. This co-ordination had been effected but was only partly successful. Only in 1976 was proper co-operation finally established.

In 1985 the orientation and wording of the title of Research Direction 2 for the subsequent five year term 1976-1980 were altered and it came to be called "The Study of Biological Productivity Processes of the Ocean". This specification wa most significant as it eliminated the then existing duplication of joint research and defined precisely the sphere of common interest of CMEA Member Countries within the present Agreement. During the same five year term, a new theme had been added in Research Direction 2, called "Investigation of the Principal Biological Processes in Marine Ecosystems as a Basis for Studying their Bioproductivity". Specialists from numerous institutes in different countries took part in a joint research on this problem which is of scientific and methodological significance.

From the very beginning of co-operation on the World Ocean Problem, preparation was planned of some general monographs on the bioproductivity of some ocean areas presenting a common interest for all member countries: the Baltic and Black Seas and the North Atlantic Ocean. This task has been fully realized and the document describing the study of the basic processes and factors that ultimately determine and shape the bioproduction of an aquatic basin has been published.

The following volumes have appeared in print: the monograph "The Principles of the Biologic Productivity of the Black Sea", prepared jointly by specialists from Bulgaria, Romania and the Soviet Union under the leadership of the Institute of Biology of the South Seas (Ukranian Academy of Sciences);the collection of papers "Oceanographic Principles of the Bioproductivity of the North Atlantic", written by scientists from the German Democratic Republic and the Sovient Union (AtlantNIRO institute); the summary treatise "Essays on the Bioproductivity of the Baltic Sea", written and edited by a large group of authors from the German Democratic Republic, Poland and the Soviet Union.

These works have a substantial value, they contain a summary and analysis of the data available in the member countries, including observations in coastal waters, which have been brought together on the basis of a standardized approach. Recently, another such monograph has been published, which deals with problems of the bioproductivity of the South Atlantic Ocean, based on data collected there in the course of expeditions of the CMEA Member Countries.

In the beginning of the working period, in 1975, two symposia were held: one in the German Democratic Republic, dealing with the bioproductivity of the North Atlantic Ocean, and another in Poland, dedicated to Baltic ecosystems. These symposia were useful in summing up national data. They showed which problems presented particular interest for diffferent countries and what practical results have been attained.

The following institutions are taking part in joint research within the scope of Research Direction 2:

- Bulgaria: Institute of Fishery Resources (Varna); Institute of Oceanology, Bulgarian Academy of Sciences (Varna); Institute of Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences (Sofia). The research group from the Institute of Nuclear Research has subsequently become a scientific body called the Task Team on Ecology.

- The GDR: Institute of Marine Research, Academy of Sciences of the German Democratic Republic (Rostock-Warnemuende); Section of Biology of Rostock University; and, to a lesser degree, Institute of Marine Fisheries (Rostock);

- Poland: Institute of Marine Fisheries (Gdynia); Institute of Oceanology, Polish Academy of Sciences (Sopot);

- Romania: Romanian Institute of Marine Research (Constanta);

- USSR: Institute of Oceanology, USSR Academy of Sciences, with its Atlatnic Branch in Kaliningrad and Southern Branch in Ghelendjik; Institute of Biology of the South Seas, Ukranian Academy of Sciences (Sebastopol) and the Institute's Odessa Branch, as well as a network of research institutions of the Ministry of Fisheries; Central Research Institute of Marine Fisheries and Oceanography (Moscow) (VNIRO) and its regional analogues, dealing respectively with research in the Azov and Black Seas, in the Baltic Sea and the Atlantic Ocean, AzCherNIRO (Kerch), BaltNIIRH (Riga), AtlantNIRO.

The following paragraphs present some basic results obtained in the course of the joint research in certain areas of the ocean.

Until recently, no co-operative CMEA expeditions had been carried out in the Baltic Sea and North Atlantic Ocean (only in the summer of 1980 did the cruise of the "Professor Siedlecki" take place, followed in 1984 by an expedition of "Akademik Kurchatov"). Each country was working on its own, the effect of co-operation being obtained through the summing up of the knowledge and the experience of specialists in the form of collective monographs. In these works some of the most prominent experts from the German Democratic Republic, Poland and the Soviet Union were responsible for the preparation of the

appropriate sections. In spite of the sketchiness implied in the title of the monograph, "Essays on the Bioproductivity of the Baltic" is a comprehensive work, covering all links of biological productivity up to the level of fish and containing a detailed description of how the scale, character and degree of the bioproductivity are affected by abiotic factors, i.e. the hydrophysical, hydrochemical, sedimentational and geochemical factors. Major portions of the book are dedicated to phytoplankton, zooplankton, ichthyoplankton and zoobenthos.

The monograph "Oceanographic Principles of the Biological Productivity of the North Atlantic" is a collection of papers prepared by members of some Soviet institutions and workers from the Institute of Marine Research of the German Democratic Republic Academy of Sciences. Besides the basic factors of the biological productivity of the Atlantic ocean, including shelf areas off northwestern Africa, the Norwegian Sea and Barents Sea, the monograph deals with the behaviour and the distribution of commercial fish resources under the influence of oceanographic factors, and the effect that the biological productivity exerts on sedimentation.

A major monograph "The Principles of Biological Productivity of the Black Sea" was issued in 1979 under the editorship of V.N. Greze, a corresponding member of the Ukranian Academy of Sciences. The monograph is the fruit of several years of concentrated labour by a large team of authors from the Soviet Union, Bulgaria and Romania who are leading scientists in the fields of marine biology, chemistry and hydrology. The work sums up the currently available information characterizing all elements of the Black Sea biological system, from planktonic algae and bacteria to fish. It also contains a description and an estimate of the Black Sea fisheries resources, according to which it seems groundless to t expect significant increases in resources and the size of catches in the near future. The fisheries in the Black Sea should proceed by harvesting the resources of the plankton feeders, anchovy and small skipjack (Caranx chrysos) and, later, also of sprat. The concluding chapter treats the mathematical modelling of ecosystems and predicts their development patterns under the impact of various factors.

In contrast to research in the Baltic, joint experimental work became very prevalent in studying the hydrobiology of the Black Sea. Thus, a series of concrete practical problems related to the influence of the Danube runoff on the bioproductivity of the northwestern Black Sea, and to the effect that the growing recreation zones exert on the biology of the coastal zone, are being tackled together by experts from the Romanian Institute of Marine Research and the Odessa Branch of the Institute of Biology of the South Seas. The work includes regular expeditions on board the research vessel "Miklukho-Maklai" of the Odessa Institute. The oceanographers collect hydrochemical and hydrobiological samples in the area influenced most heavily by the Danube runoff, and then plot distribution charts of salinity, oxygen, silica, phosphate, organic phosphorus, nitrites, suspended matter, etc. The high concentration of biogenic substances in the near-Danube area was shown to cause an intensive bloom of diatom algae and accumulation of organic matter near the bottom. The mineralization of the organic matter results in the deficit of oxygen in the near-bottom layer causing mass extinction of bottom and demersal organisms - musssels, shrimp, crabs, bullhead (Cottus), plaice.

The study of the suppression of coastal ecosystems, as a consequence of beach protection works in recreation zones, has indicated that the quantity of aquatic organisms sharply decreases in such situations. These organisms include some algal species, sponges, mussels, decapods, bullhead and other organisms which play a prominent part in the self-cleaning capability of the sea. As a result, the quality of the marine environment deteriorates progressively. New methods and recommendations are being developed with the aim of increasing the quantity of these organisms and promoting the biological improvement of the coastl zone.

Tri-lateral research of the processes governing the bioproductivity of the Black Sea, carried out by Bulgarian, Romanian and Soviet institutes, was initially to be realized within the national frameworks on the basis of a common co-ordination plan. Such a plan had been put into practice, and envisaged mainly the investigation of the budget of the organic and biogenic substances which had been determined, as well as appropriate exchange of information on the northern, northwestern and western sectors of the Black Sea. However, the effective co-operation was not limited to this. One can cite other examples of closer scientific ties. In particular, the Institute of Biology of the South Seas (Sebastopol) has undertaken a more accurate reassessment of the value of the biological production in some Black Sea areas, that was based on the answers given by experts from co-operating institutions to a special questionnaire. The joint biological hydrochemical expedition on board the Soviet vessel "Skif" in the pelagic part of the Black Sea should also be noted. Besides the spring 1979 research related to the bioproductivity indicators, the expeditionary research has produced new information pertaining to the general chemical characteristics of western Black Sea waters.

Joint research also took place in the Black Sea on another theme, aimed at studying processes in the marine ecosystems. The main object of this research was to accumulate information on the structural, energy, and other characteristics of the ecosystems, and on interrelation and response of these characteristics to various factors (including anthropogenic), and to predict the ecosystems' subsequent state and development with the aid of mathematical modelling.

The first joint experiment on this subject was convened in 1977 in Sozopol (Bulgaria), where experts from the CMEA member countries demonstrated and compared methods for measuring the biological and hydrochemical parameters in natural marine conditions; concurrently, a scientific seminar on the same subject was also held. During the experiment, it was decided to conduct an expedition in the open portion of the Black Sea. The expedition onboard the R/V "Vityaz" was headed by Prof. M.E. Vinogradov (Shirshov Institute of Oceanology, USSR Academy of Sciences) and conducted in October and November 1978. The expedition was a landmark in the study of biological processes in the Black Sea. The staff of the expedition numbered 40 Soviet scientists and 13 oceanographers from Bulgaria, the German Democratic Republic, Poland and Romania. The programme of research was fairly broad, encompassing hydrological, hydrochemical and other observations needed for investigating the pelagic ecosystem of the Black Sea. Much importance was attached to methodological work, the intercalibration of different instruments and automatic data collection. In this respect, the work of the Vityaz expedition was highly rated among other experimental research carried out earlier.

The principal goal of the expedition consisted in the study of the pelagic community in the Black Sea and the details of its functioning during the period of research. The approaches employed were based on the principles and methodology developed by the workers from the Shirshov Institute of Oceanology (USSR Academy of Sciences) in the course of preceding prolonged studies into the functioning of the oceanic pelagic communities.

A salient feature of the Vityaz expedition was the making of repeated stations of several days duration with the collection of a complex of data on the water properties and the organisms in the water column. A major part of the data processing was accomplished directly on board the vessel. The comparative analysis of the results of the various lines of research has provided a solid base for assessing the energy budget of the pelagic community and its functional characteristics. Some experimental research has also been done and has produced new information.

The automated instruments for measuring some biogenic elements (various forms of nitrogen and phosphorus compounds) have contributed to the construction of a detailed picture of the temporal variability of the compounds. The scientists established that the bulk of nitrate and phosphate stock is concentrated in the layer between the pycnocline and the upper boundary of hydrogen sulphide. This implies, that intermixing, when weak, can become a limiting factor for phytoplankton development. The expedition used a hydrological probe coupled with a water sampling device equipped with a system of sensors and recording units for pressure, temperature, electric conductivity, dissolved oxygen and some other state variables. This enabled a detailed knowledge of the physico-chemical parameters to be obtained over the vertical length of the water column, and samples of the water and organisms to be taken at such depths and under such conditions when the most respresentative results could be reasonably expected. In parallel, soundings with the "Quant-2" transparency meter were also performed giving the possibility of precisely pinpointing the layers with the enhanced or reduced transparency.

The hydrochemical and hydrophysical observations have revealed a substantial diurnal variability of the decomposition processes. There seems to be a related change in the activity of various bacterial populations. The lack of a regular correlation between the values of decomposition and those of primary production implies that organic matter is apparently utilized by bacteria which is especially true of the allochthonous organic matter.

The systematic measurement of the in situ primary production has permitted the obtaining of a more reliable value for the primary production and a detailed description of the vertical structure of photosynthesis. The lower boundary of the photosynthetic zone has been shown to lie at the depth where irradiation is only 0.1 % of thesurf-ace irradiation. This figure is less by an order of magnitude thanthe universally accepted lowest level of photosynthetic irradiance of 1%.

The expedition carried on research, begun earlier, on developing realiable techniques for calculating primary production without using buoy stations. A new indicator of specific production has been proposed which is the light assimilating capacity of chlorophyl.

Several procedures were used simultaneously to determine the chlorophyl concentrations. These included the standard extraction method, the method of measurements on filters (without extraction), and the direct measurement in water samples. All the methods employed produced comparable results, but the latter turned out to be the most sensitive. It revealed the occurrence of a noticeable quantity of chlorophyl at a depth of 90 to 140 metres which was not found by other methods. Besides this, the chlorophyl concentrations in the surface layer were measured by a remote procedure with the help of a twin wavelength spectrophotometer, as were the carotinoids which were also determined by thin-layer chromotography.

Important results were obtained from studying the composition and distribution of the phytoplankton and zooplankton species. The experts concluded that the organisms in the oxygen zone can seemingly be viewed as a single community. Diurnal variations of the amount of algae are relatively small. According to observations during the expedition,this is due, in particular, to two processes: (i) phytoplankton grazing by the zooplankton (mainly during the night hours, the grazed amount makes up 80% of the diurnal production) and (ii) the proven intensive division of the phytoplankton cells which also takes place at night.

The microbiological research has furnished information on the organisms inhabiting the layer between the oxygenated and hydrogen sulphide zones. This layer is found to be characteristically abundant in chemosynthesizing bacteria, whose production amounts to 25% of the phytoplanktonic production. It has also been established that the consumers of these bacteria are the zooflagellates and some specific infusoria.

Utilisation of an underwater television system has permitted prolonged observations and assessment of the amount of jellyfish in Black Sea waters. It was widely assumed that the number of jellyfish, which is a trophic dead-end of the planktonic community, has lately been growing in the Black Sea. The in situ underwater observations corroborated this view.

The results of the "Vityaz" expedition attracted the attention of oceanogrpahers from the CMEA countries, and shortly after the end of the cruise they were discussed at a special symposium in Rostock (German Democratic Republic) held in January 1979. Considering high scientific value of the research and its significance not only for the Black Sea but other seas as well, the symposium recommended that the results of all the research be published in the Soviet Union and the German Democratic Republic. The first volume entitled "Ecosystems of the Pelagic Black Sea Areas" appeared in 1980.

The same symposium in Rostock considered plans for future work on this topic. It was decided to distinguish two separate lines of investigation, the first dealing with ecosystems of the coastal zone, and the second with ecosystems of pelagic areas. During the subsequent years, the research focused mainly on the first subject. During the working meetings in Varna in 1979 and Moscow in 1980, a range (polygon) off Sozopol in Bulgaria was designated for long-term biological research and a broad inter-disciplinary programme of ecosystem research, was detailed. To a certain extent, this biological range together with a biolaboratory available in Sozopol, is similar to the "Kamchia" hydrophysical complex which is also situated in Bulgaria and

designed for long-term joint research. The introduction of such advanced forms of co-operation will produce valuable scientific results and is a tangible step towards the establishment of a permanent co-operative basis for oceanographic research for the CMEA Member Countries.

In September 1980, the specialists from Bulgaria, the German Democratic Republic and the Soviet Union carried out joint research on the coastal ecosystems, which was of three weeks duration and marked the beginning of the agreed long-term programme. The scientists commenced to study a multitude of the component variables needed for developing models of the functioning of coastal ecosystems and predicting the behaviour of these coastal ecosystems under changing environmental conditions in the coming years. It was proposed that these studies be done both on the seasonal and long-term aspects. The pilot experiment involved measurement of the temperature, optical irradiance at different levels, oxygen concentration, Ph and oxidation-reduction potential, the phytoplankton and bacterial production, were estimated, and samples of bacterioplankton, phytoplankton and micro-meso and macrozoolplankton samples were collected. The species ans size composition of the organisms were evaluated, as were their numbers and biomass.

At the same time, experiments were performed on the feeding of the zooplankton on the plants and bacteria. The principal biocoenoses of the demersal population in the polygon area have been determined and pertinent information has been collected, which has enabled the composition and distribution of the micro - meso and macrobenthos to be analysed. Special measurements were made of the macrophyte production, the oxygen fluxes through the sea sediment interface and the anaerobic fluxes in the sediments.

During the summer season of 1981 the Soviet research vessel "Akadamik L. Orbeli" was used in these investigations. In subsequent years, the experimental research into the functioning of the coastal ecosystem was performed on a regular basis. This work is being done by international teams of scientists supported by Soviet research ships. Thus in 1985, the Sozopol area was surveyed from the R/V "Rift" of the Shirshov Institute of Oceanology which was equipped with the manned undersea vehicle "Argus".

On the basis of this research, the Co-ordinating Centre published in 1985 a collection of papers under the title "The Structure and Functioning of the Coastal Ecosystem of the Western Black Sea (area off Sozopol, Bulgaria)".

In August-September 1980, a Baltic expedition was conducted on board the Polish vessel "Professor Siedlecki" which was an international event due to the participation of some scientists from the Shirshov Institute of Oceanology (USSR Academy of Sciences). The expedition geographically covered the central and southern Baltic Sea. Although the expedition bore an interdisciplinary character, its general purpose was the study of the pelagic ecosystem and, especially, more specifically, of primerary production. A large amount of new data was collected bearing on one of the most fundamental problems of the Baltic: i.e. the oceanographic and ecological linkages of different bioproduction levels. It should be noted, that the new data resulted from the concurrent detailed interdisciplinary investigation of multiple environmental factors.

During the Baltic cruise of the "Professor Siedlecki" (Poland) the scientists proceeded with in situ research on the light assimilation capacity of phytoplankton initiated on board the "Vityaz" in 1978 in the Black Sea. Data on the capacity of the living phytoplankers to assimilate solar radiation in various spectral ranges provide the basis for the accurate evaluation of the photosynthesis efficiency, which is of theoretical and practical importance, for instance, in the modelling of the primary production. The light-assimilation capacity of phytoplankton can be used as a mesure of autotrophic plankton biomass; a correspondingly indirect assessment of the primary production might be possible.

A new "Vityaz" expedition was carried out in the Black Sea in the spring of 1984. The major tasks of the expedition were to make estimates of the biological and fishery productivity and to do research within the framework of the Soviet "Ecosystem" project whose purpose is the study of the structure and laws ofthe functioning of sea and open ocean ecosystems. A prominent part of the expedition's activities was given to exploration under the CMEA theme "The Structural and Functional Investigation of Marine Ecosystems as the Basis for Evaluating their Productivity and the Degree of Anthropogenic Impact (eutrophication, heavy metals, etc)". This research was undertaken along the guidelines of a programme prepared at the Shirshov Institute of Oceanology. Practical work was done by an international team of Bulgarian, Polish, Cuban and Soviet Scientists. The specialists from these countries conducted the following operations: Bulgaria - measurement of the vertical profile of the dissolved oxygen and the study of the horizontal and vertical distribution of the oil-oxidizing heterotrophic microorganisms; Poland - measurement of the optical characteristics required for determining the dependence of the rate of photosynthesis on the available light energy and the determination of the efficiency of energy utilisation in the process of photosynthesis; Cuba - study of phytoplankton, collection of data on microzooplankton, and sampling of some species for optical measurements.

The tasks set before the expedition were accomplished. In addition to much other data, substantial new information on the structure and functioning of the Black Sea pelagic ecosystem was obtained and the changes due to the influence of human economic activity have been evaluated with reference to analogous data from the "Vityaz" cruise of 1978.

In May-June 1984, another expedition on the large Soviet Research Vessel "Akademik Kurchatov" was conducted in the Baltic Sea. Its principal aim was the collection of the data needed for the modelling of primary production. A significant result of this research was the obtaining of a series of empirical relationships connecting the light field at different depths with the primary production, in the particular conditions of a shallow sea experiencing strong human impact.

A collection of papers entitled "Assimilation of Solar Energy in the Process of Photosynthesis by Black Sea and Baltic Phytoplankton" has been published by the Co-ordinating Centre, Moscow, 1985.

In summary, within the framework of Research Direction 2 dealing with problems of biological productivity, new data have been obtained, the available information on the geology of the Black and Baltic Seas has been summed up, and several collections of papers have been published discussing these problems for some areas, including the North Atlantic and The Southern Ocean. Substantial results were produced at the experimental range in the Black Sea off Sozopol, Bulgaria.

RESEARCH DIRECTION 3

The Study of the Chemical Processes in the Ocean

The programme and plans of research within the Research Direction 3, dedicated to the study of chemical processes occurring in the marine environment, have undergone drastic modifications over the past period of more than a decade, these modifica- tions being caused by a search for a more effective mode of joint research. In the first five year period, stemming from the immediate practical importance of the subject, the title of the direction was worded as "The Study of the State of Pollution of the Open Sea Areas in the Black Sea and the Baltic Sea and of the Processes of the Turbulent Diffusion of Contaminants". The principal goal was to obtain systematic data on the pollution of the open part of the Black and Baltic Seas and improve methods for calculating turbulent diffusion of contaminants under the conditions of tideless seas. As with the biological research described above, such a general statement of the objective was not especially serviceable, since it also implied a considerable duplication of effort and repeated the subjects on wich hydrometeorological services of the same countries were already pursuing their own particular co-operation programmes. Therefore in the second five year period 1976-1980, the objective was changed. Nevertheless between 1971 and 1975, it had been possible to organize some useful activities(which are further described below), viz to conduct two expeditions dedicated to the standardization of procedures for the chemical analysis of sea waters, to hold a symposium on brakish sea pollution, and to prepare a jointly written book "Methodological Manual for the Chemical Analysis of Marine Waters for CMEA Member Countries".

The first of the expeditions in question took place in the Baltic on the German Democratic Republic vessel "Professor A. Penk" in late 1973. The participants consisted of some members of the State Oceanographic Institute (Moscow) and the Institute of Marine Research (German Democratic Republic Academy of Sciences). The chief purpose of the research was the standardization of the procedures for the chemical analysis of sea water by joint work on board the ship and by obtaining immediate knowledge of each other's methodology. Incidental new data were obtained on the influence of the North Sea on the Baltic pollution. This research indicates that the bottom waters of the North Sea entering the Baltic Sea are far more contaminated with ammonium nitrate, mercury and other pollutants than the Baltic waters proper in the Danish Islands area. This evidence runs contrary to the earlier prevailing notion that the Baltic Sea is the most polluted of all the seas bordering Europe.

In April 1974, another expedition was organized, this one on the Soviet ship "Ernst Krenkel" in the Black Sea, with 80 participating scientists from Bulgaria, Poland, Romania and the Soviet Union. The standardization of the procedures for the chemical analysis of sea water was once again the chief purpose of the expedition. The Soviet scientists aquainted their colleagues with the 15 methods of analysis adopted in the Soviet Union, as well as with other observation and measurement techniques and with the processing of on board hydrological and meteorological observations.

The symposium held in Gdynia (Poland) during January 1974 on "Pollution of Brackish Seas" was a big event with a total of 50 presented papers. The papers emphasized the particular ecological conditions of brackish seas, where the interaction of the river and sea components of the aquatic environment is taking place. Under the conditions of brackish seas with densely populated coastal regions and slow water exchange with the ocean, the stratification of the water masses, affecting vertical transport of pollutants, becomes especially crucial. As a rule, the typically layered structure of the water masses leads to the accumulation of pollutants in the deep-water zone, whence, under certain conditions, they may penetrate into near-surface layers.

Parallel to this work and partially on the basis of it, the "Methodological Manual for the Chemical Analysis of Sea Waters for CMEA Member Countries" was being prepared. In 1977 it was finally published in Poland. The manual was compiled by a group of 39 experts representing all Member Countries of the Agreement. The book is divided into three main sections:

1. Sampling and preservation techniques for sea water;

2. Methods of determining the principal physico-chemical indicators of the state of the marine environment.

3. Methods for identifying and measuring major pollutants contained in sea water.

The chief purpose of the Manual was to summarize the experience of the scientists from the Socialist countries in the field of the chemical analysis of sea water. It was not, however confined solely to this purpose. The Manualal also presented a step towards the advancement and standardization of the measurement techniques which could make comparable different data obtained in the national expeditions of individual countries.

The published Manual was well received both by the marine cnemists from the co-operating institutions and by the chemical community in general. It was considered to be a valuable result of co-operation. A helpful event in the preparation of the Manual was the international seminar on methods of determination of chemical pollution of marine and oceanic waters, held in Odessa in 1975.

The publication of the Manual seemed to draw a line under the research of the first five year period. Beginning from 1976, the chemical side of co-operation acquired a new title "The Investigation of Chemical Processes in the Ocean". Within this general heading which stresses the study of the basic processes, some more specific themes have been identified dealing with (i) the improvement of chemical sampling and analytical procedures, (ii) the chemical structure and processes in the Baltic and Black Seas and (iii) the problems of the chemical exchange between different water masses.

As concerns improving chemical sampling and analytical procedures, a whole series of laboratory exercises has been organized and conducted on the intercalibration of the methods for determining the content of various compounds in sea water, suspended matter, interstitial waters, etc., and on the treatment of the results obtained by these methods. In particular, during the abovementioned expedition of the R/V Ernst Krenkel" in October 1978 in the region off Odessa, the methods for determining various forms of nitrogen in sea water were compared and deviations analysed.

During the past several years, some joint laboratory work on the intercalibration of the measurement procedures concerning the content of organic matter, oxygen and other components of sea water has been accomplished by the Institute of Marine Research, German Democratic Republic Academy of Sciences, the Institute of Oceanography of Gdansk University and the Shirsov Institute of Oceanology, USSR Academy of Sciences. The results obtained by different procedures were analysed and the causes of discrepancies identified. Recently, a large intercalibration exercise, covering a three year period, has been conducted to compare the techniques for measuring trace metal concentrations in sea water samples, which had been distributed by post by the German Democratic Republic Institute of Marine Research that initiated this joint venture. Numerous institutions from all co-operating countries took part in this intercalibration, including even those organizations that were not formal partners in the joint programmes.

Presumably, research of a methodological nature will continue in the years to come. It would be expedient to create international teams that would jointly develop analytical instruments and equipment.

The hydrochemical research on the Baltic and Black Seas within the Agreement's framework was mostly of a supporting nature and was performed in relation to biological problems. Thus, extensive programmes of hydrochemical investigations were carried out during the above-mentioned biological cruises of the "Vityaz" in 1978, "Skif" in 1979, and later expeditions. Other research was performed by each country according to its own national plans, and co-operation was confined to the exchange of information.

Of a promising nature is the theme dedicated to a separable utilisation of sea water to yield some of its valuable chemical components and a supply of drinkable or industrial water. This theme is purely practical, as shown by the ultimate applicability of its results. Nevertheless, to attain the ultimate goal of developing commercial technologies and the construction of prototype units, it is necessary to conduct considerable exploratory research, including the establishment of the seasonal and annual variation of the essential elements in the chemical composition of the raw material, i.e. the sea water in the chosen working area of Bulgaria. In 1979 at a meting in Varna, representatives of Bulgaria, Poland and the Soviet Union agreed on a long-term research programme envisaging theoretical and experimental investigation of the problem, the study of the technical feasibility of various component-extraction procedures, and, ultimately, the development of the technology for the water desalination and the extraction of some products from the brines.

In the autumn of 1980, at the facilities of the Higher Institution for Chemical Technology in Burgas (Bulgaria), the first Soviet-Bulgarian experimental studies were organized on the extraction, by selective sorption, of some valuable chemical elements from natural Black Sea water and its brines, obtained from a commercial salt works in its basins where the initial evaporation was done. The major task was to explore the absorptive capacity of various types of sorbents with respect to the trace elements. Of special interest were the experiments on brines from which the bulk of the calcium ions had been removed: the selectivity of sorption is dependent on the conditions under which the sorption processes operate; therefore, the selective properties of the different types of polymeric sorbents may become substantially modified with a change in the character of processed electrolytic solution.

The last subject of the chemical division, the "Study of the Exchange of Chemical Elements at the Interfaces in the Marine Environment", was only recently proposed by Poland for joint research. The results obtained in this field, besides their basic significance for the analysis of the global cycle of chemical elements, may find quite a number of practical applications in various sectors of human activity, including environmental control and protection. In late 1980, an international seminar was held at the Shirsov Institute of Oceanology (USSR Academy of Sciences) attended by participants from Bulgaria, Cuba, the German Democratic Republic, and Poland. The leading experts from these countries presented contributions synthesizing the available national research experience and informed the delegates of the latest findings; the papers of the seminar were published by the Co-ordinating Centre in the form of a special volume.

In subsequent years, the research in this field branched into two directions: the Baltic countries (the German Democratic Republic, Poland and the Soviet Union) became active in joiont experimental studies of air/sea chemical interaction and, particularly, in the atmospheric aerosols and the influx of solid matter from the atmosphere into the sea, whereas in the Black See, Bulgaria and the Soviet Union have been conducting in situ experiments on the exchange of chemical species between the sea and the bottom sediemnts, including the fate of pollutants deposited on the bottom. These latter experiments have already produced an abundance of new information and promise to produce more. The international participation in this research is likely to brooden in the future.

RESEARCH DIRECTION 4

The study of the Geological History and Recent Sedimentation Processes in the Ocean

Joint research along these lines within the framework of the Agreement was begun by CMEA member-countries in 1973. During the subsequent period, the principal forms of co-operation included marine expeditions on the continental shelf of the Baltic and Black Seas, common processing and analysis of the results obtained and eventual preparation of international monographs.

The initial geophysical work on the GDR part of the Baltic shelf was conducted on the R/V "Seebad Zingst" in the autumn of 1973. During this cruise, the Soviet specialists from the Shirshov Institute of Oceanology tested an underwater gamma-ray measuring device developed and made at their institute. The purpose of this work was the lithological mapping of the shelf and, in particular, the location of bottom sites, having an elevated heavy mineral content, with the help of continuous radiometric survey equipment.

In summer 1974, this research was resumed. It was the first known case in marine geological research where the continuous litholo-radiometric mapping method was used for examining heavy mineral placers in shallow areas far removed from the shoreline.

To define the course of future research in the Baltic and Black Seas, the first international symposium on the geological history of those seas was convened in Tallin, USSR, in December 1974. The symposium was attended by 70 scientists from 30 institutions of Bulgaria, the German Democratic Republic, Poland and the Soviet Union. The participants had the opportunity to discuss some complicated and controversial issues concerning the geological history of the Baltic and Black Seas, which enabled constructive proposals for refining Holocene and Pleistocene stratigraphy to be offered and working plans of joint research to be developed for the coming years.

In 1974 the first Soviet-Bulgarian expedition was conducted in the Bulgarian shelf zone off the Black Sea. It was manned by scientists from the Southern Branch of the Shirshov Institute of Oceanology and from the Institute of Oceanology (Bulgarian Academy of Sciences) aboard R/V "Akademic L. Orbeli". The aim of the expedition was the study of the sedimentary mantle of the shelf and continental slope to get a better understanding of the Quaternary and Holocene history of the Black Sea basin. This research was continued on the same vessel in August/September 1975, and September/November 1976.

The most interesting discovery of the expedition was a marginal bank which was traced along all the explored continental shelf perifery at a depth of 90 to 110 m. The formation of this bank is apparently related to the regression of the Black Sea due to the lowering of sea level in late Pleistocene. The bank is likely to extend along all the periphery of the Black Sea shelf.

The collected research data indicate, that the shelf was formed stage by stage due to the erosion of the outcropping basement rock during the Quaternary transgressions of the Black Sea and the establishment of a regional slope directed towards the Black Sea basin. The findings of the expeditions were used to prepare a Soviet-Bulgarian monograph "Geology and Hydrology of the Western Black Sea", published in Bulgaria in 1979. The data systematized in this work have both theoretical and economical value, since they provide the geological basis for assessing the prospecting potential of the continental slope resources.

July 1975 was the start of the first Soviet-Polish expedition in the Baltic Sea on board the Soviet vessel "Professor Dobrynin". This research was later carried on by workers from the Atlantic Branch of the Shirshov Institute of Oceanology, Department of Geography (Lithuanian Academy of Sciences), Polish Institute of Meteorology and Hydrology, Institute of Oceanography of Gdansk University, Institute of Marine Research (German Democratic Republic, Academy of Sciences) and Greifswald University, on the vessels "Professor A. Penk" (German Democratic Republic), "Hydromet" (Poland), "Professor Dobrynin" (USSR) and "Shelf" (USSR).

By the continuous radiometric surveying technique developed at the Shirshov Institute of Oceanology, combined with sediment sampling, the percentage content of heavy minerals of commercial interest was studied in the bottom sediments from a ship under way. As a result, the areas of bottom sediments with differing heavy mineral content have been mapped, and the pattern of their location on the sea bottom has been studied. In addition, new morphological, morphometric and lithobiostratigraphic data have also been collected on the ancient coastal formations and on the detailed composition of the Quaternary sediments which will be useful for the geological mapping of the bottom and the paleogeographical reconstruction of the late and post-glacial development of the Baltic Sea.

During the research, a lithostratigraphic method for the determination of late Quaternary deposits was developed and is being constantly improved. It allows a broad correlation to be made between tens and hundreds of cores, by means of both biostratigraphic and absolute dating based on a relatively small number of reference cores. Concurrently, the geochemical investigation of the sediments for paleogeographic purposes is also being carried out. The study of the salt composition of interstitial waters and the permiability of cores from the deeper troughs has allowed important conclusions to be made as to the late-glacial penetration of saline water into the Baltic basin. The analysis of samples of spores and pollen suspended in the atmosphere has provided a synoptic picture of the distribution of this suspended material over the Gdansk basin of the Baltic Sea.

The research results were discussed at two symposia. One symposium - on the stratigraphy, geomorphology and paleogeography of the central and southern Baltic basins - was held in Vilnius, USSR, in 1979, which attracted 63 scientists from 25 organisations of Bulgaria, the German Democratic Republic, Poland and the Soviet Union (31 papers were presented).

In July 1980, a joint expedition was carried out on the German Democratic Vessel "Alexander von Humbolt", dedicated to the study of the submarine and subaerial coastal formations of the Arkona basin and

Mecklenburg Bight. This research produced new data on the structure of the late Quaternary sedimemnts of the western Baltic basin. The ancient coastal formations of the Ancylus Lake time in the Arkona basin and Mecklenburg Bight are represented by former peat bogs and gyttja. Samples of these deposits were taken to perform radioactive dating so as to determine the times of Holocene transgression-regression cycles of the Baltic Seas, which are of importance for elucidating some controversial aspects in the history of the basin's development.

During September/October of the same year (1980), another joint expedition studied the sedimentation processes and the development of the Gdansk deep during the Holocene and late Pleistocene epochs. As a result, new data on the detailed structure of the upper sedimentary layer of the Gdansk basin have been collected, ancient shorelines on the Sambian-Kursch submarine plateau traced, several cores taken from the ancient coastal formations of the Holocene basins, and samples of the basement rocks obtained in two vibrocore holes. The problem of mapping the ancient shorelines in this region can be solved by studying corresponding geomorphological features and by pinpointing the existing structural sediment traps. Therefore this research should be carried on off shore where ancient coastal forms are more abundant and represented by a wider range of facies. An impportant result of the expedition is the proven possibility of geological mapping of the south western Baltic bottom with the help of profiler of the "Huntec" type, and vibrocoring.

The results obtained will be employed for compiling a spectogramme of the submarine and subaerial shorelines, which will constitute a major advance concerning the paleogeography of the Baltic sea. The study of the distribution, character, morphology and sediments of the marine shorelines will make it possible to improve planning of the prospection for concentrated placer minerals, amber, phosphates, etc. This gives the abovementioned research a practical orientation. The identification of deformed shorelines will be a useful criterion in the search for recent tectonic deformations and for structures having a possible link to subsurface oil-bearing formations.

The obtained data were also used for correlating the submarine and subaerial shore formations of the southern and central Baltic Sea. This subject was treated in two monographs: "Litho and Biostratigraphy of Late and Post Glacial Deposits of the Baltic Sea" (1981) and "The processes of Sediment Accumulation in the Gdansk Basin of the Baltic Sea" (1982).

In October, 1977 a joint geological/geophysical expedition was conducted on the Soviet vessel "Moscow University" over the northern Bulgarian continental shelf. This was an extension of the research begun during the cruises of the "Akademic L. Orbeli". Besides the seismo-acoustical research, the programme included special exploratory work in the Kamchia international hydrophysical and oceanographic research range and the surrounding shelf areas, intended to provide detailed knowledge of the structure of upper geological layers (down to a water depth of 2,000 m) and involved the taking of sediment samples.

In 1978-1979 this programme was continued, first from the R/V "Moscow University" and then from the R/V "Horizont". The partners in the joint endeavour consisted of Moscow University (Faculty of Geology), the Institute of Oceanology and the Geological Institute (both of the Bulgarian Academy of Sciences), Sofia University, and the Bulgarian Committee on Geology.

In October-November 1980 still another Soviet-Bulgarian expedition was carried out in the northwestern and western Black Sea on the Soviet ship "Geokhimik" (meaning geochemist). It resulted in identifying a 45 metre thick stratum of Holocene sediemnts on the shelf on Coketrice Bank and Spitfire Bank.

The aim of the joint expedition on board the Soviet R/V "Horizont" in November/December 1980 was the investigation of the structure of the upper sediment cover and the determination of the lithofacies distribution of shelf sediments, including their composition, thickness and bedding structures, as well as aspects of the geological structure of the western Black Sea. The expedition furnished abundant data on the geological structure of the area in question. A system of intricate canyons or valleys more than 400 metres deep was discovered in the border zone of the shelf and the continental slope at the latitude of Constanta. The composition of the sediments and their pattern of occurrence indicate that, in the time preceding upper New-Euxinian, the level of the Black Sea was at least 400 metres lower than at present, whereas the valleys were parts of the ancient Danube river system. Besides that, the seismic profiling has revealed that the western Baltic shorline has moved a considerable distance westwards over a relatively short time span.

New facts accumulated during the expedition permit the Cainozoic development history of all the western part of the Black Sea to be known in much greater detail than was previously possible. In addition, the information can be used in studying the oil-bearing potential of Cainozoic deposits in south western and western shelf areas, as well as in selecting routes for laying down underwater communication cables, chosing sites for offshore enginering projects, zoning of seismic rick on the adjacent land, etc.

The sum of all the conducted joint expeditions gives a clear understanding of the physical and mechanical properties of bottom deposits of some Bulgarian shelf areas; it has been shown that organic matter exerts an appreciable influence on those properties. The study of the tectonic structure has proved the existence of a south-eastern seaward extension of the Staraya Planina (Greater Balkan) ridge. Accordingly, the dimensions of the marine portion of the lower Kamchia marginal trough can be assumed to a much greater extent than it was earlier believed.

At the request of the Bulgarian Committee on Geology, the tectonic structure of the marine portion of Tiulenevo oil deposit with its large potential resources has been carefully studied. Detailed surveys were conducted over the "Samotino-more" anticline which has permitted a large cross fault to be located, the flanks of the fold to be traced and, consequently, its size, as reflected in the Cainozoic deposit, to be determined. A detailed survey of the structure of the upper sedimentary layers has been made in the area of possible future drilling of deep prospecting holes for oil and gas. The results obtained are being utilized in developing methodology for studying the engineering properties of the bottom as a foundation for drilling installations. The comprehensive investigation of the geological structure has permitted an estimate to be made of oil and gas prospects of the Cainozoic deposits of the whole Bulgarian continental terrace.

The research materials were used to prepare a joint collection of papers, "Geological-geophysical Studies of the Bulgarian Sector of the Black Sea", published in Bulgaria in 1980.

In general, considerable progress has been achieved in CMEA member countries during the past years in studying the geology of the Black Sea and the Baltic Sea, with respect to paleogeography, the composition of the Quaternary sediments and their age sequences, as well as the tectonic structure. As to the purely methodological aspect of the research, a distinctive qualitative advance has recently occurred.

RESEARCH DIRECTION 5.

The application of the Submarine Research Technology
to the Exploration of the Sea

Research Direction 5 was included in the programme of co-operation at the Fifth Meeting of the Council of Representatives in October 1974. This decision was facilitated by the successful conduct of two underwater experiments during the "Shelf-Chernomor" project in 1973 and 1974, using a manned undersea habitat devised at the Shirshov Institute of Oceanology.

Among the participants in the 1973 experiment of the "Shelf-Chernomor" project were staff of the Shirshov Institute of Oceanology (USSR), Research Institute for Fishery and Oceanography (Bulgaria) and some invited specialists from other Soviet and Bulgarian organisations. There were also observers present from the German Democratic Republic. The suppport vessels in the experiment were the R/V "Akademik L. Orbeli" (USSR) and R/V "September 9" (Bulgaria). The overall number of participants exceeded 100.

Since the experiment was the first of its kind for the co-operating countries, attention was focused on problems of the organization and strengthening of supporting services and on the search for optimum forms of joint scientific and technological investigation involving the concerned institutions. Particular attention was paid to the problems of medical support and to the creation of safe conditions for the crew under the extreme conditions of underwater work. Scientific research in the hydro-optical, ichthyological, medico-physiological and psychological programmes was accomplished during the experiment.

All scientific programmes realized by the crew of the undersea habitat, the medical support group and the on-shore hydro-optical group were original and were consecrated to fundamental research. Thus, the data of hydro-optical studies have permitted the mathematical model of light distribution in the sea to be improved, and the behaviour of the transfer function relating to surface waves and fluctuations of the underwater light field to be examined.

Within the framework of the ichthyological programme, the scientists investigated the effect of water pressure on trout, which was found to influence predominantly the fish's hydrostatic organ, the swim bladder. If pressure is increased swiftly, the bladder becomes unable to regulate the intake and exhaust of gases, and, consequently, a trout experiences difficulties in adjusting itself to such altered environmental conditions. Also, one should not ignore the effect of water temperature on trout. In some cases, this may cause disturbances in the fish's breathing balance.

The "Shelf-Chernomor" project experiment has demonstrated the advanced level of the experts from the Member Countries and their ability to solve rather complex problems combining practical oceanology with physiology. The organisation of the work during the preparatory period and in the course of the experiment was efficient and of good quality. This work was continued in the following year (1974) with the participation of all interested countries.

The underwater experiment of 1974 attracted 116 specialists from Bulgaria, the German Democratic Republic and the Soviet Union. Its interdisciplinary research programme included oceanographic investigations (hydro-optics, hydrochemistry, hydrodynamics of the near-bottom layer, investigation of recent sedimentation processes, testing of a vibrodrill serviced by aquanauts and testing of a portable submarine TV camera), a comparative study of the efficiency of different types of SCUBA diving equipment for use in undersea habitats, and comprehensive neurophysiological and neuropsychological observations on the state of the aquanauts.

In studying the statistical characteristics of the underwater light field, nearly 80 recordings of light field fluctuations have been amassed. From those data, it was later possible to establish the relationship between surface waves and the statistical characteristics of the underwater light field at different levels, and to deduce some relevant correlations.

Using the vibrodrill, the aquanauts took tow sediment cores, each 6 metres long. The portable television camera had excellent image quality and has proved to be a useful instrument for underwater biological sediment transport and archeological research. A large amount of data was produced by the neurophysiological, psychometric, electrocardiographic and respiratory examinations of the aquanauts from the undersea habitat, and the supporting SCUBA divers.

The examinations also concerned hearing capability, the vestibular apparatus, the co-ordination of movements, the gas composition of the blood and the mechanical working ability of the aquanauts and support divers. The information collected in the medico-physiological examinations is useful, primarily, for developing a strict methodology for the medical regulation of aquanauts during operations at great depth.

An important consequence of the experiment was an improvement in the forms of international co-operation in the conduct of undersea research projects.

The organisation of the divers' work in the experiments at first presented severe difficulties. This had above all to do with discrepancies in the safety provisions for diving. According to the rules in effect in the Soviet Union, in all cases a signal line, which provides the possibility of continuous communication between the diver and the surface support group (or person), is absolutely required. According to Bulgarian regulations, the signal line is used only in exceptional cases, such as during a rough sea state. Under normal conditions, divers work underwater in pairs. Similar regulations exist in Romania and some other countries. The participants in the experiment were unprepared for a radical solution to this problem, and separate systems of work were adopted for Bulgarian and Soviet divers. Consequently, there arose an important and urgent problem, the development of common rules for SCUBA diving operations for CMEA member countries.

Safety rules for SCUBA diving operations during underwater research in joint expeditions of CMEA Member Countries, were prepared and published in 1978. This laborious work was accomplished by experts from Bulgaria, the German Democratic Republic and the Soviet Union. The Safety Rules duly account for the special aspects of undersea research and the particularities in organising deep dives and diving operations under conditions where divers (aquanauts) make prolonged stays under water or under an elevated pressure of a surrounding gas medium.

At present, the uniform Safety Rules have been officially adopted in the Soviet Union, Bulgaria and the German Democratic Republic.

From 1975 to 1978 in Research Direction 5, joint research was conducted on the subject "The Development of Methodology and the Study of the Functioning of Men and Animals under Hyperbaric Conditions". The partners were the Central Laboratory of Brain Studies in Bulgaria, Sechenov Institute of Evolutionary Physiology, Shirshov Institute of Oceanology (USSR Academy of Sciences), and Bogomolets Institute of Physiology (Ukrainian Academy of Sciences).

The work followed two distinctive lines: some experiments on the morphology of the brain and other organs of aminals subjected to prolonged hyperbaric effect which were staged by the Bulgarian Brain Laboratory and Sechenov Institute (from Leningrad), and another series of experiments dealing with man's prolonged stay at a pressure of 10 atm, organized by the Southern Branch of Shirshov Institute of Oceanology, Bogomolets Institute of Physiology, Bulgarian Central Brain Laboratory, and Institute of Oceanology of the Bulgarian Academy of Sciences.

The first of the abovementioned lines of research was discontinued and dropped from the common programme in 1979 at the request of Bulgaria.

The first experiment in the second line took place in March/April 1978 at the Southern Branch of Shirshov Institute of Oceanology, using the hyperbaric complex GKK-DN-300 available there, with the objective of investigating human reactions to a prolonged stay at a pressure of 10 atmospheres in a helium-oxygen medium. The Shirshov Institute of Oceanology and its Southern Branch assured general organisation of the work and technical maintenance and operation of the equipment, whereas the Bogomolets Institute of Physiology and the Central Laboratory for Brain Studies conducted medico-physiological investigations.

New information has been obtained, characterizing the functional state of the higher nervous activity, breathing, blood circulation, oxygen regime and the dynamics of human biochemical indicators. The possibility of man's adaptation to a depth of 100 metres without a significant functional impairement was confirmed.

The overall methodological and instrumental standard of the research conducted is on a good international level in this field.

Within another theme of this Research Direction, "The Development of Technical Means and Methodology for Deep Underwater Diving Operations", with the technical advice and medico-physiological guidance of Soviet experts (Southern Branch of the Institute of Oceanology), the Bulgarian partner (Institute of Oceanology), in 1980 constructed a diving engineering device permitting dives down to 100 metres depth. This programme was expanded in 1978 with a new theme called "The Development of Methodology and the Conduct of Shelf Studies with the Use of Submarine Vehicles". In the summer of 1979, specialists from the USSR and Bulgaria carried out an expedition in the Black Sea on board a Soviet Union R/V "Aquanaut" to perfect the research methodology using the underwater remotely-controlled vehicle "Manta - 1.5" and the towed vehicle "Zvuk-4".

The "Manta-1.5" is designed for surveying the bottom surface by means of a television camera, and collecting rock and water samples to a water depth of up to 1.5 km. The "Zvuk-4" vehicle is used in deep-water acoustic geophysical surveys for exploring and identifiying forms on the bottom surface, fissures, faults, etc., as well as for studying non-consolidated stratified sediments; it has a working depth range from the surface to 2,000 metres.

In July 1980, a new Soviet-Bulgarian geophysical expedition on board the "Aquanaut" was conducted in the Bulgarian shelf area; it involved the use of the "Zvuk-4 m" (modified version) and "Manta-0.2" (working water depth range to 200 metres) vehicles. Four ranges were established for special study on the shelf and upper continental slope. These ranges were specifically set in geologically differing regions so that the research could provide detailed information on the geological structure and character of the unconsolidated sediments, and resolve some methodological problems connected with the operation of the vehicles in shallow waters. In the areas in question more than 200 kilometres of acoustical profiling were done, more than 1,000 photographs were taken, and three hours of television observations were made. It has been demonstrated in practice, that the use of such new technology as towed vehicles for geophysical research on the shelf is more efficient in comparison to traditional methods. Acoustical profiling from towed vehicles gives a quicker recovery of detailed information on the bottom surface and sediments over large areas.

A preliminary comparison of the acoustic recordings of unconsolidated sediment thickness to data obtained with bottom corers has shown fairly good correlation. The results produced by the joint expedition will have practical application in the selection of sites for drilling rigs on the Bulgarian shelf. The combination of acoustic and visual observation methods has provided a multidisciplinary approach to the research conducted.

It has been established that remote-controlled devices are very advantageous to use in areas with outcrops of basement rocks.

Investigations using guided and towed devices presumably will be continued in the years to come. Their practical worth is evident, and the obtained data make them useful for all the co-operating countries.

An expedition on the Cuban shelf took place on board the R/V "Rift" of the Shirshov Institute of Oceanology in 1983. The main working area was the Caribbean Sea (shelf, island slope and base of the island of Cuba). The participants in the expedition included Soviet scientists, 14 persons from Cuba, and 2 Bulgarian experts. The manned submersible "Argus" made 45 dives, and the "Zvuk" vehicle was towed 18 times. The crews of the submersible consisted of Soviet and Cuban personnel. The expedition was primarily oriented towards special geomorphological and hydrobiological research, which could be done with the submersible and the towed device. For the first time, direct visual geomorphologic exploration of the bottom was realized on the island shelf of Cuba.

SPECIALISED ACADEMIC TRAINING AND UPGRADING OF PROFESSIONAL STANDARDS

The development of oceanographic research on the World Ocean Problem has required the upgrading of academic qualifications and training highly professional specialists. The Co-ordinating Centre has been organizing post-graduate courses, apprenticeship visits and participation in large expeditions. This has been a regular activity since 1973.

Apprenticeship visits have become a popular form of training as a common co-operative practice. Annually, the Co-ordinating Centre organizes about 10 apprenticeship visits to institutes in other countreis. In the interval 1971-1975, 22 scientists from Bulgaria, the German Democratic Republic, Poland and Romania passed apprenticeship periods within the framework of the Agreement. In 1976-1980 such visiting scientists from the same countries, plus the Republic of Cuba, totalled 53. The apprentices were received at academic and educational institutions of the German Democratic Republic, Poland and the Soviet Union. In 1981-1984 54 scientists from Bulgaria, the German Democratic Republic, Cuba and Poland passed apprenticeship periods, their number growing in toto and in each country. These figures show that apprenticeship has become a commonly used form for training highly qualified researchers for all the countries concerned. This trend continues at present.

The subject matter of the apprenticeships mostly concerned the themes of research pursued within the programme of scientific co-operation. The indicators, characterizing the reception of apprentices from 1973 to 1980 according to the different directions of research, are the following:

- Direction 1: 55% of all the received scientists.
- Direction 2: 15% " " "
- Direction 3: 10% " " "
- Direction 4: 18% " " "
- Direction 5: 2% " " "

In the most recent years, this proportion has gradually changed towards an increased role of biological Direction 2.

Some progress has been made in such forms of training as normal and extra-mural post-graduate courses. However, the requirements of the partner organisations in post-graduate training are not as yet fully net. In the period 1981-1984, only six candidates were accepted through the Coordinating Centre for such courses. A large potential exists here for further progress, which should be exploited. The number of institutions which offer the possibility of post-graduate training evidently needs to be increased. The subject matter of the post-graduate theses should be closely linked to the solution of problems directly included in the programme of

co-operation. It is known from experience, that those workers who are directly engaged in joint research and, consequently, have the possibility to consult numerous experts and to use the data of experimental investigations performed under the Agreement, complete their post-graduate course with invariable success.

Yet another way of upgrading professional qualifications is through participation of scientists in international task teams. This method is difficult to evaluate in quantifiable terms, but its impact is very high. Scientists have benefitted significantly by participating in the abovementioned major experiments in Zingst, Lubiatowo and Kamchia and in the expeditions of "Vityaz", "Skif", Alexander von Humbolt", "Hydromet", "Shelf", "Aquanaut" and others. Personal contacts of the participants and common activity at all stages of research from the preparation of a draft prgramme to the summing up of the results, enrich the scientists and contribute to the growth of their skills. Prominent experts share their experience with younger colleagues, during research and symposia, and acquaint them with the details of their methodology.

On the whole, the efforts connected with upgrading the qualifications of oceanographers in the member countries of the Agreement occupied noticeable place in all joint activities and had an appreciable success, which was one of the prime results of the co-operation.

PUBLISHING ACTIVITIES

The results of the joint research on the World Ocean Problem, as well as current information, are regularly published in the member countries.

During a realtively short time span between 1972 and 1980, a number of information bulletins and works were published (see Annex). These works summarize the experience available in partner countries, reflect the common ideas and conclusion of the international teams participating in the joint experiments, contain analysis and proposals for national and international research programmes, make methodological recommendations, etc. The overall volume of publications amounted to some 430 folios produced by 420 authors from five countries. Results of joint research have been published by the institutes and state publishing firms of various countries: Bulgaria, the German Democratic Republic, Poland the Soviet Union. In 1981-1985, 10 more monographs and joint works were published (see Annex).

As of 1986, 20 issues of the Co-ordinating Centre's information Bulletin have been published. The Bulletins mostly include reviews of international experiments and proceedings of conferences, reports to the Council of Representatives, review of other publications of the Co-ordinating Centre and of the Shirshov Institute of Oceanology. The latest achievements in marine sciences and prospects for the recovery of the oceans' resources are also reviewed and published in the Bulletins.

CONCLUSIONS

The research results obtained in all Research Directions of Co-operation have been highly valued by experts in the member countries and have become widely known through the published monographs and collections of papers.

To assess the accumulated effects of the co-operation the following major achievements and salient points need to be stressed:

1. The research realized within the framework of the World Ocean Problem has substantially augmented the pool of knowledge in many fields of oceanography. In particular, our understanding of the heat and mass-exchange mechanisms between the sea and the atmosphere was much improved. New data have been obtained necessary for constructing an ecosystem model for the Black Sea. The results of national research on the bioproductivity and ecosystems of the Baltic Sea have been co-operatively analyzed and interpreted. Moreover, co-operative biological experimenental investigations have been initiated in the Baltic Sea on a large scale. For the same sea, the laws and patterns of occurrence of some chemical components in the sediments have been determined. Information produced by geological-geophysical studies in the Bulgarian sector of the Black Sea can be used in planning the prospection for oil and gas on the Bulgarian continental terrace. An extensive programme of physiological investigations dealing with sea dives and man's prolonged stay under water has been successfully accomplished.

   The obtained results have provided the necessary scientific foundation for solving problems of practical significance in several fields: hydrometeorology, navigation, fisheries, marine pollution protection, and sea technology. Some of the published works contain direct practical recommenations for state economic organizations.

   A considerable amount of scientific information has been collected for future analysis; some subjects, that began to be pursued in recent years, hold promise of yeilding good results of a basic and applied character in the near future. These include inter alia, the development of a substantially non-linear model of the Black Sea hydrophysical fields and the study of the possibilities for utilization of chemicals and water from the sea.

2. The programme of joint research on the World Ocean Problem has grown more rational with time. At present, it appears to be well thought out, not duplicating other CMEA programmes, and complying with the national interests of the co-operating countries. A flexible system of planning has been put into effect, consisting of relatively long-range five-year plans, plus the continually updated two-year plans, and a plan for the current year. In view of the substantial time required for preparing large experiments and expeditions, this practice turned out to be most effective.

3. There has been a large institutional growth and development of the institutions due to co-ooperative research. A special Institute of Oceanology has been created in the Bulgarian Academy of Sciences; and a separate Programme Team on Ecology has been formed, entrusted with conducting complex experimental research on the functioning of near-coastal ecosystems. The Bulgarian Academy of Sciences made a

capital contribution to the co-operation on the World Ocean Problem, having built a unique marine research gallery with shore facilities in the Kamchia region, having organized an experimental station for biological investigations in the area of Sozopol, and, having constructed the new "Shkorpilovtsy" experimental research complex.

An important development was the inclusion, as a co-operative institution, of the "Lubiatowo" experimental facility belonging to the Water Engineering Institute of the Polish Academy of Sciences. The Department of Oceanology of the Polish Academy of Sciences was constantly expanded during this period, and has lately been transformed into the Institute of Oceanology.

The international experiments and expeditions have been regularly supported by research vessels from the USSR, Poland, Bulgaria and the German Democratic Republic.

4. By means of joint research, stable ties have been established between the scientists of the co-operating countries. International teams have been organized to solve specific tasks. These teams work on different themes within in each of the major Research Directions. The teams have their own systems of work which by now have become precise and effective. From the initial stating of objectives to the final processing and analyzing of the information, such teams produce important results.

   The excellent performance of international task teams is a principal organisational achievement of co-operation. It is this trait that enabled some very substantial results to be obtained in quite a short time. As a concrete example of the resultant efficiency, the acceleration rate of the scientific research due to international co-operation could be estimated to be 3 or 4 fold. In other words, the results thus obtained over a period of 3 to 4 years would require a period of 10 to 12 years within the framework of a purely national programme.

   The work of international teams is an important achievement of the CMEA community in general, and in the World Ocean Problem in particular.

5. Substantial possibilities exist for training. Joint practical work at sea and in the laboratory, organisation of apprenticeship visits and post-graduate course - such are various means enabling young scientists to share the available knowledge and experience. During the period of co-operation, many young researchers have prepared their theses and obtained their scientific degrees; in addition, there has been a marked growth in the overall level and qualification of all the scientific community participating in the joint projects.

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